

WHAT WE CLAIM IS:

1. A control apparatus for controlling a shift operation in an automatic transmission having plural shift stages to be established by selecting plural friction engagement elements to be engaged or disengaged, wherein an off-going friction engagement element of the plural friction engagement elements is switched from an engaged condition to a disengaged condition by reducing torque transmitted to the off-going friction engagement element at a time of shifting from a shift stage of the plural shift stages to the other shift stage thereof such that the off-going friction engagement element slips, and an on-coming friction engagement element of the plural friction engagement elements is switched from a disengaged condition to an engaged condition by increasing torque to be transmitted to the on-coming friction engagement element at the time of shifting, the control apparatus comprising:
 - 15 a slip amount calculating means for calculating a slip amount based upon a rotational speed of an input shaft of the automatic transmission and a rotational speed of an output shaft thereof;
 - 20 a judging means for judging whether or not the calculated slip amount is greater than a predetermined threshold value by comparison;
 - 25 a target slip amount calculating means for calculating a target slip amount, the target slip amount varied from the predetermined threshold value to a predetermined target value drawing an ideal trace for restraining a shift shock and maintained at the predetermined target value;
 - 30 a disengaging side controlling means for performing a feedback control so as to substantially match the calculated slip amount with the calculated target slip amount when the calculated slip amount is judged to be in excess of the predetermined threshold value by the judging means; and
 - 35 an engaging side controlling means for increasing the torque to be transmitted to the on-coming friction engagement element in association with commencement of the feedback control.
2. A control apparatus for controlling a shift operation in an automatic transmission having plural shift stages to be established by selecting plural friction engagement elements to be engaged or disengaged along with control of an oil pressure to be supplied thereto, wherein an off-going friction engagement element of the plural friction engagement elements is switched

from an engaged condition to a disengaged condition by reducing torque transmitted to the off-going friction engagement element in response to reduction of the oil pressure supplied to the off-going friction engagement element at a time of shifting from a shift stage of the plural shift stages to the

5 other shift stage thereof such that the off-going friction engagement element slips, and an on-coming friction engagement element of the plural friction engagement elements is switched from a disengaged condition to an engaged condition by increasing torque to be transmitted to the on-coming friction engagement element in response to increase of the oil pressure to be supplied

10 to the on-coming friction engagement element at the time of shifting, the control apparatus comprising:

 a slip amount calculating means for calculating a slip amount based upon a rotational speed of an input shaft of the automatic transmission and a rotational speed of an output shaft thereof;

15 a judging means for judging whether or not the calculated slip amount is greater than a predetermined threshold value by comparison;

 a target slip amount calculating means for calculating a target slip amount, the target slip amount varied from the predetermined threshold value to a predetermined target value drawing an ideal trace for restraining a shift shock

20 and maintained at the predetermined target value;

 a disengaging side controlling means for performing a feedback control so as to substantially match the calculated slip amount with the calculated target slip amount when the calculated slip amount is judged to be in excess of the predetermined threshold value by the judging means; and

25 an engaging side controlling means for increasing the torque to be transmitted to the on-coming friction engagement element in association with commencement of the feedback control.

3. A control apparatus for controlling a shift operation in an automatic transmission according to claim 2, wherein the engaging side controlling means increases the oil pressure supplied to the on-coming friction engagement element to a level of a stand-by pressure which does not generate the torque at the time of shifting, maintains the oil pressure being supplied to the on-coming friction engagement element at the stand-by pressure level until

30 commencement of the feedback control, and increases the oil pressure being supplied to the on-coming friction engagement element to a level of an oil

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pressure required for shifting to an inertia phase after the commencement of the feedback control.

4. 1 A control apparatus for controlling a shift operation in an automatic transmission according to claim 1, wherein the slip amount to be compared with the predetermined threshold value by the judging means corresponds to a slip amount applied with a first filtering process for eliminating a first predetermined frequency component from the slip amount, and the slip amount controlled to be substantially matched with the target slip amount by the disengaging side controlling means corresponds to a slip amount calculated based upon the input shaft rotational speed and the output shaft rotational speed applied with a third filtering process for eliminating a third predetermined frequency component from the output shaft rotational speed.
- 15 5. A control apparatus for controlling a shift operation in an automatic transmission according to claim 2, wherein the slip amount to be compared with the predetermined threshold value by the judging means corresponds to a slip amount applied with a first filtering process for eliminating a first predetermined frequency component from the slip amount, and the slip amount controlled to be substantially matched with the target slip amount by the disengaging side controlling means corresponds to a slip amount calculated based upon the input shaft rotational speed and the output shaft rotational speed applied with a third filtering process for eliminating a third predetermined frequency component from the output shaft rotational speed.
- 20 6. A control apparatus for controlling a shift operation in an automatic transmission according to claim 4, wherein the slip amount controlled to be substantially matched with the target slip amount by the disengaging side controlling means corresponds to a slip amount calculated based upon the input shaft rotational speed applied with a second filtering process for eliminating a second predetermined frequency component from the input shaft rotational speed.
- 25 7. A control apparatus for controlling a shift operation in an automatic transmission according to claim 5, wherein the slip amount controlled to be substantially matched with the target slip amount by the disengaging side
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controlling means corresponds to a slip amount calculated based upon the input shaft rotational speed applied with a second filtering process for eliminating a second predetermined frequency component from the input shaft rotational speed.

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8. A control apparatus for controlling a shift operation in an automatic transmission according to claim 1 further comprising:

a lock-up clutch capable of connecting the input shaft of the automatic transmission and the output shaft thereof, wherein the disengaging side controlling means sets a control gain for the feedback control at different values depending on an engaged / disengaged condition of the lock-up clutch.

9. A control apparatus for controlling a shift operation in an automatic transmission according to claim 2 further comprising:

15 a lock-up clutch capable of connecting the input shaft of the automatic transmission and the output shaft thereof, wherein the disengaging side controlling means sets a control gain for the feedback control at different values depending on an engaged / disengaged condition of the lock-up clutch.

20 10. A control apparatus for controlling a shift operation in an automatic transmission according to claim 1 further comprising,

a reference model included in the target slip amount calculating means and capable of outputting the target slip amount when the reference model is inputted with a value variable in a stair step manner from the predetermined threshold value to the predetermined target value, and

25 an error feedback controlling means for feedbacking an error between the slip amount calculated by the slip amount calculating means and the target slip amount outputted from the reference model.

30 11. A control apparatus for controlling a shift operation in an automatic transmission according to claim 2 further comprising,

a reference model included in the target slip amount calculating means and capable of outputting the target slip amount when the reference model is inputted with a value variable in a stair step manner from the predetermined threshold value to the predetermined target value, and

35 an error feedback controlling means for feedbacking an error between

the slip amount calculated by the slip amount calculating means and the target slip amount outputted from the reference model.

12. A method of designing a control apparatus for controlling a shift operation
5 in an automatic transmission having plural shift stages to be established by selecting plural friction engagement elements to be engaged or disengaged, wherein an off-going friction engagement element of the plural friction engagement elements is switched from an engaged condition to a disengaged condition by reducing torque transmitted to the off-going friction engagement
10 element at a time of shifting from a shift stage of the plural shift stages to the other shift stage thereof such that the off-going friction engagement element slips, and an on-coming friction engagement element of the plural friction engagement elements is switched from a disengaged condition to an engaged condition by increasing torque to be transmitted to the on-coming friction engagement element at the time of shifting, the method of designing comprising steps of:
15 interpreting a response characteristic of a slip amount relative to an input to the automatic transmission as a transfer function within a frequency domain;
defining a reference model capable of obtaining an ideal slip amount
20 response characteristic for restraining a shift shock;
constructing a feedback control system provided with an integral-proportional controller relative to the interpreted transfer function of the automatic transmission; and
25 adjusting a proportional gain and an integral gain for the integral-proportional controller so as to substantially correspond or approximate the response characteristic of the slip amount in the feedback control system to the ideal response characteristic of the reference model.